RESEARCH

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# Environmental impact assessment of missile test firing

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## ABSTRACT

Combustion of propellant during missile test firing generates a lot of toxic gaseous pollutants in to the local atmosphere. During 2011–13, there were 17 No of test firing of different types of missiles from LC - I, LC-II & LC-III in Chandipur & LC-IV in Dhamra. To find out the concentration of toxic gases after test firing, monitoring of gases were carried out an hour after test firing and tested for different parameters like RPM, $SO_2$, $NO_X$, CO, HCN & Cl. From the results it was found that all the parameters were well within the prescribed norm before and after rocket firing, but during rocket firing RPM values were above the standard norm of 100µg/m$^3$. These values also became normal within an hour. Other parameters were found well within the standard norm during the rocket firing.

**Keywords**: Ambient Air Quality, Exhaust Product, Rocket Firing, Integrated Test Range.

**Abbreviations:** LC - Launch Complex; GF/A Glass - Micro Filter Paper; RPM - Respirable Particulate Matter; CPCB - Central Pollution Control Board; $SO_2$ - Sulphur Dioxide; PXE - Proof & Experimental Establishment; NOX - Nitrous Oxide; RFNA - Red Fuming Nitric

Acid; CO - Carbon Monoxide; ITR - Integrated Test Range; HCN - Hidrogen Cyanide; DRDO - Defense Research Development Organisation; AP - Ammonium Perchlorate; HTPB - Hydroxy Terminated Poly Butadiene

## 1. INTRODUCTION

Air is one of the five basic natural ingredients of life system. Air pollution may be described as the presence of air pollutants in the atmosphere to such an extent that they cause deleterious effect. Rapid industrialization, year after year, introduction of faster mode of transport and sprouting up large crowed cities or urbanisation are the main outcome of the modern civilisation. These are contributing to environmental pollution (Sharma, 2004). Rocket motor is a device or an engine that converts chemical energy into mechanical motion. Hot gases are produced in combustion chambers of jets and rockets by burning a fuel with oxygen or an oxidizer. Many of the present solid propellant systems contain composite propellant which consists of an energetic oxidizer (Ammonium perchlorate, AP), a plasticizer to facilitate processing, a metallic fuel (Aluminum, Al), a polymeric binder (Hydroxy terminated polybutadiene, HTPB) which also acts as a fuel and other additives (Diisocyanates) that are needed for the curing of the propellant. These propellants being nitrogen rich are likely to produce $N_2$, $H_2O$, $O_2$, NO, HCL, NOCL, $NO_3$ and $NO_2$ etc. during decomposition (Sutton, 1992). AP has been extensively used in propellant compositions and it gives out HCl in the exhaust that attenuates radar waves that guide the missile, which is the biggest disadvantage. In case of composite propellants presence of HCN emission is due to Diisocyanate curing agents like toulene diisocyanate or isophoron diisocyanate (Panda, 2000; Sahu, 1998). A typical liquid propellant consists of G-fuel (equal mixture of xylidene and triethylamine) and Red Fuming Nitric Acid (RFNA) is used by missiles. Triethylamine with very high vapour pressure is a big fire hazard. Xylidene is toxic whereas triethylamine is a strong irritant (Tables 1 to 3). Thus, launching of rockets & missiles from a test range produces a lot of toxic gaseous exhaust and pollutants which are let in to the local atmosphere. To ascertain environmental safety of these toxic exhaust products there was a need to conduct study of nature of the combustion products and their quantitative estimation. Hence the present study was proposed to estimate the air pollution load in terms of RPM, Oxides of Nitrogen and Oxides of Sulphur at different timing of rocket firing (before firing, during firing and after firing) in Integrated Test Range, DRDO, Chandipur in the year of 2011-2013. Theoretical exhaust product analysis of the above propellant compositions was carried out by computer software NASA CEC -71 (Sahu, 2009).

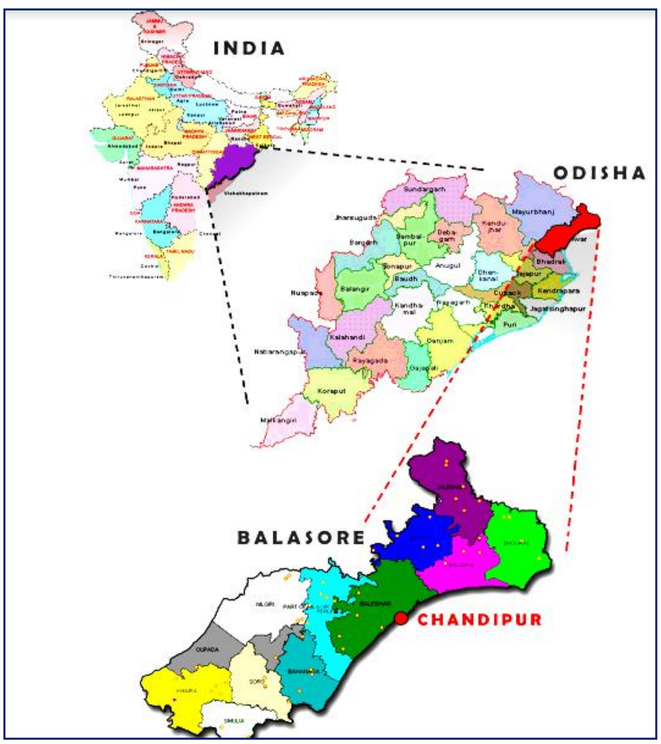


**Figure 1**

Location Map of the Study Area

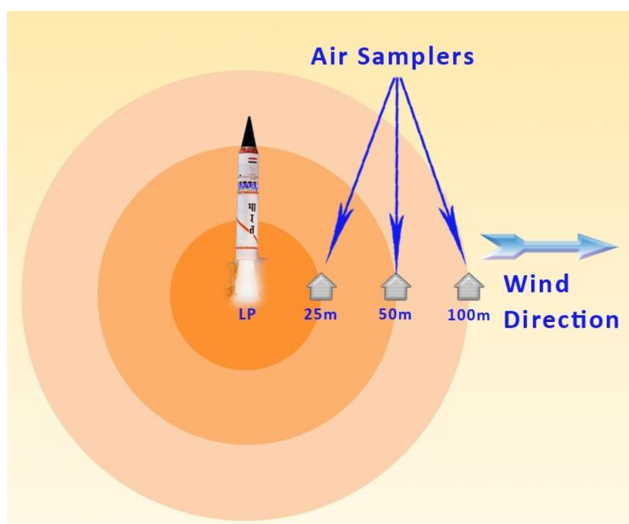


**Figure 2**

Collection of gaseous exhaust with the help of Air Samplers

## 2. STUDY AREA

Balasore, one of the coastal districts of Odisha, lies on the northern most part of the state having $21^0$ 03' to $21^0$ 59' North Latitude

& 86$^0$ 20′ to 87$^0$ 29′ East Longitude. Geographical area of the District is 3634 Sq. Km. Midnapore District of West Bengal is to its North, the Bay of Bengal on the East and Bhadrak District lies to the South whereas Mayurbhanj and Kendujhar Districts are on its Western side (Figure 1). As per 2011 India Census, Balasore has a population of 20,40,000. Integrated Test Range (ITR), Chandipur was taken as the center of study. It is situated on the coast of Bay of Bengal in Balasore District of Odisha. In this region, sand dunes are noticed along the coast with some ridges. This region is mostly flooded with brackish water of estuarine rivers which is unsuitable for cultivation. But, presently this area is utilized for coconut and betel plantation. Shrimp culture and salt manufacturing units have also come up in this area relatively recently. The second contiguous geographical region is the deltaic alluvial plain. The soil of Balasore District is mostly alluvial laterite. The soil of the central region is mostly clay, clay loam and sandy loam which is very fertile for paddy and other farm produces. Nilgiri Sub-Division comprises of gravel and lateritic soil, which are less fertile. A small strip of saline soil is also seen along the extreme coastal part of the district where ITR and PXE are located. The climate of Balasore District is mostly hot and humid like the majority of the coastal belt of Odisha. The summer season is between March & May which is followed by rainy season from June to September. During this period, South-West Monsoon causes maximum rain. But the district experiences highest rain fall during July/August. Because of its geographical location, this district faces most of the cyclonic storm and depression which occur in the Bay of Bengal. The winter season is from December to February.

**Table 1**

Mole fraction of combustion gaseous exhaust product of Double Base Propellant

| Composition | Chamber | Throat | Exit |
|---|---|---|---|
| $CH_4$ | 6.70E -08 | 8.20E-08 | 5.70E-06 |
| CO | 4.26E-01 | 4.20E-01 | 3.45E-01 |
| $CO_2$ | 1.05E-01 | 1.10E-01 | 1.86E-01 |
| H | 1.25E-03 | 4.80E-04 | 1.93E-08 |
| HCO | 6.39E-05 | 2.83E-05 | 2.76E-08 |
| $H_2$ | 1.36E-01 | 1.42E-01 | 2.17E-01 |
| $H_2O$ | 2.06E-01 | 2.01E-01 | 1.26E-01 |
| $NH_3$ | 1.23E-05 | 9.85E-06 | 1.01E-05 |
| NO | 2.67E-05 | 5.00E-06 | 0.00E+00 |
| $N_2$ | 1.23E-01 | 1.23E-01 | 1.23-01 |
| OH | 4.04E-04 | 1.04E-04 | 0.00E+00 |
| PBO(S) | 0.00E+00 | 0.00E+00 | 1.48E-03 |
| PBO (G) | 1.74E-03 | 1.69E-03 | 1.44E-04 |
| PBH | 4.76E-04 | 5.27E-04 | 5.98E-04 |
| | 1.00E+00 | 1.00E+00 | 1.00E+00 |

**Table 2**

Mole fraction of combustion gaseous exhaust product of Nitramine Propellant

| Composition | Chamber | Throat | Exit |
|---|---|---|---|
| CO | 3.16E-01 | 3.12E-01 | 2.69E-01 |
| $CO_2$ | 1.83E-01 | 1.89E-01 | 2.34E-01 |
| H | 5.31E-03 | 3.24E-03 | 3.82E-06 |
| HCO | 6.90E-05 | 3.75E-05 | 1.66E-07 |
| $H_2$ | 6.19E-02 | 6.41E-02 | 1.07E-01 |
| $H_2O$ | 2.61E-01 | 2.64E-01 | 2.26E-01 |
| NO | 1.36E-03 | 5.35E-04 | 0.00E+00 |
| $N_2$ | 1.62E-01 | 1.63E-01 | 1.64E-01 |
| O | 4.08E-04 | 1.20E-04 | 0.00E+00 |
| OH | 7.76E-03 | 3.76E-03 | 2.04E-07 |
| $O_2$ | 6.97E-04 | 2.02E-04 | 0.00E+00 |
| PBO(G) | 7.86E-04 | 7.91E-04 | 7.03E-04 |
| PBH | 3.21E-05 | 3.12E-05 | 1.22E-04 |
| | 1.00E+00 | 1.00E+00 | 1.00E+00 |

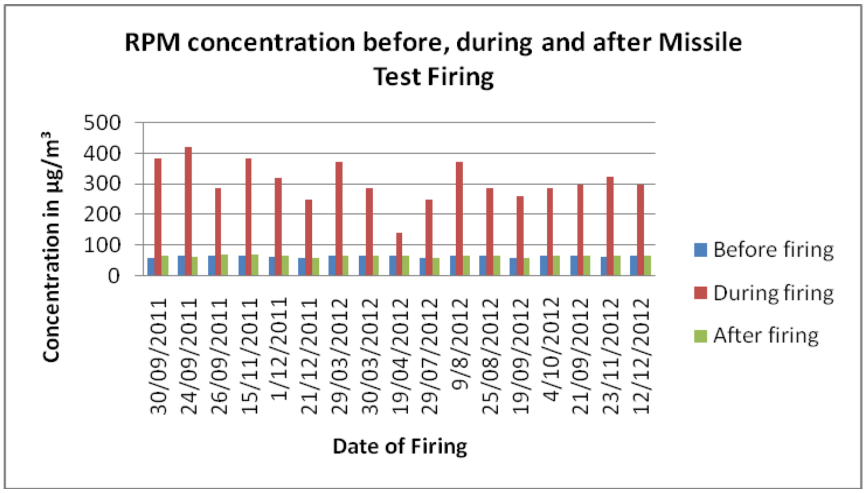


**Figure 3**

RPM concentration in the Ambient Air before, during and after Missile Test Firing

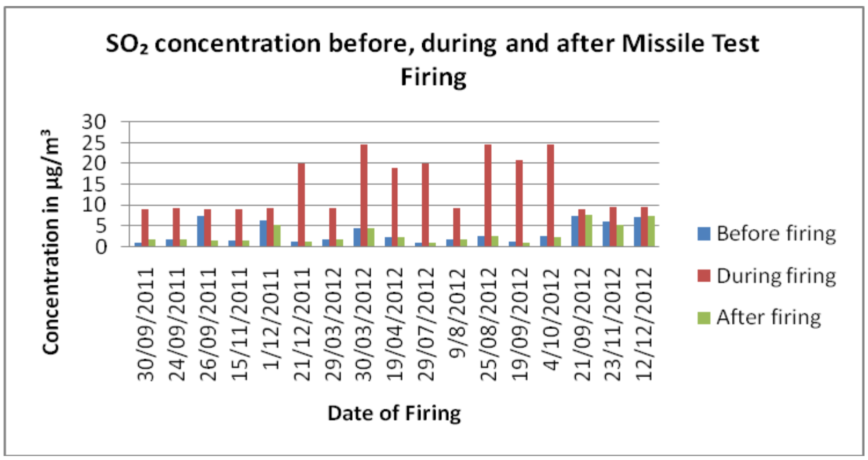


**Figure 4**

$SO_2$ concentration in the Ambient Air before, during and after Missile Test Firing

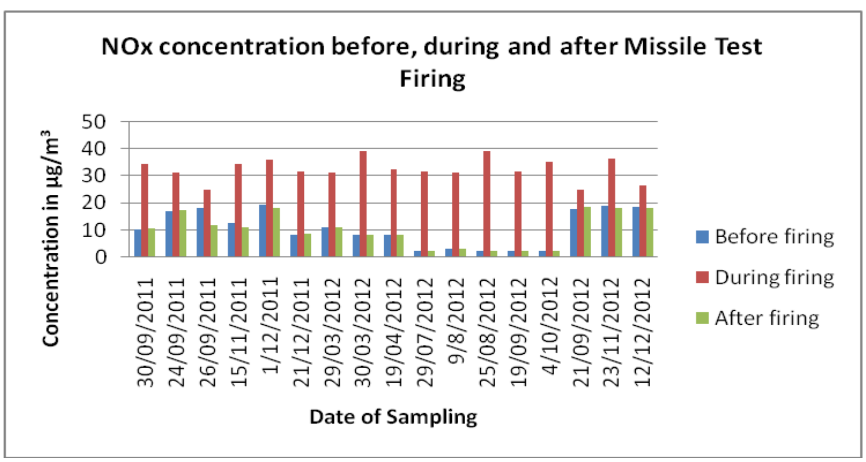


**Figure 5**

$NO_X$ concentration in the Ambient Air before, during and after Missile Test Firing

## 3. MATERIALS AND METHODS

Exhaust product analysis have been carried out theoretically by computer software, NASA-CEC-71 to identify toxic emissions of rocket combustion. Actual field measurement of toxic exhausts has been carried out by deploying Air Samplers at predetermined locations near launch pad during missile launching (Figure 2). For monitoring Ambient Air Quality, High Volume Air Sampler APM-415 (Environtech make) and Respirable Dust Sampler APM-460 (Environtech make) were used. GF/A glass micro filter paper have been used for monitoring of SPM (Suspended Particulate Matter) and RPM (Respirable Particulate Matter), (Figure 3). The $SO_2$ and $NO_X$ have been monitored through High Volume Air Sampler attached with gas sampler. The $SO_2$ pollutant has been monitored through sodium tetra chloro mercurate and analyzed by spectrophotometric method (West and Gaeke, 1956). Similarly $NO_X$ has been monitored through sodium arsenate solution as absorbent and analyzed by using phosphoric acid, sulphanilamide, hydrogen peroxide and NEDA (1-napthyl ethylene diamine dihydro chloride) through spectrophotometer (Jacob and Hochheiser, 1958; APHA, 1977). Sound pressure level was measured by help of dB meter. Comparison of theoretical and field measurement data with national ambient air quality standard and its impact on human health has been carried out to assess the safety zone for missile launching.

## 4. RESULTS AND DISCUSSION

In order to evaluate the effect of test firing on air quality and structures various environmental parameters were monitored before firing, during firing and after an hour of test firing for each missile firing, results of which are presented in the graph 3 to graph 9. During 2011–13, there were 17 No of test firing of different types of missiles from LC - I, LC-II & LC-III in Chandipur & LC-IV in Dhamra on different dates. From the result it has been found that before test firing, in all LCs at Chandipur and Dhamra the RPM concentration was found to be between 55.0 to 65 µg/m³, which is well within the ambient air quality safety standard of 100 µg/m³ as prescribed by CPCB (Panigrahi, 2012). The monitored value of RPM during test firing of different rockets at ITR Chandipur and Dhamra were within the range of 138 µg/m³ to 420 µg/m³. The values were different for different missiles depending on the propellant content and these were momentarily higher

than the prescribed standard of CPCB i.e., 100 µg/m[3]. To know the persistence of pollutant in the atmosphere, monitoring of RPM was done an hour after the test firing of different missiles at Chandipur and Dhamra.

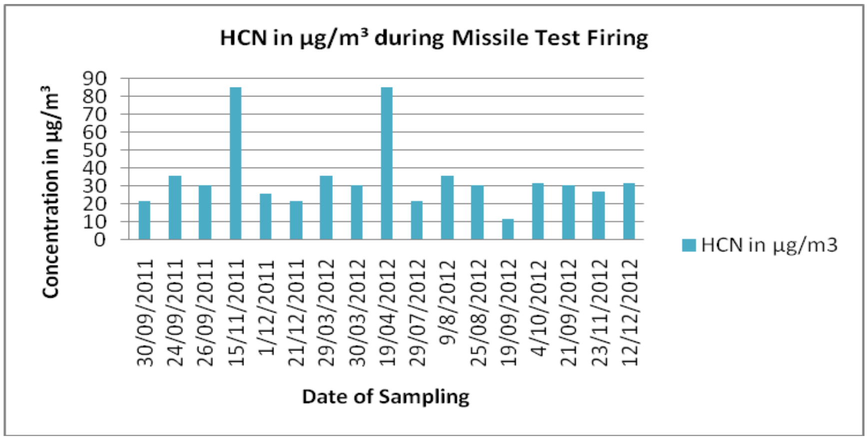


**Figure 6**

HCN in µg/m³ during Missile Test Firing

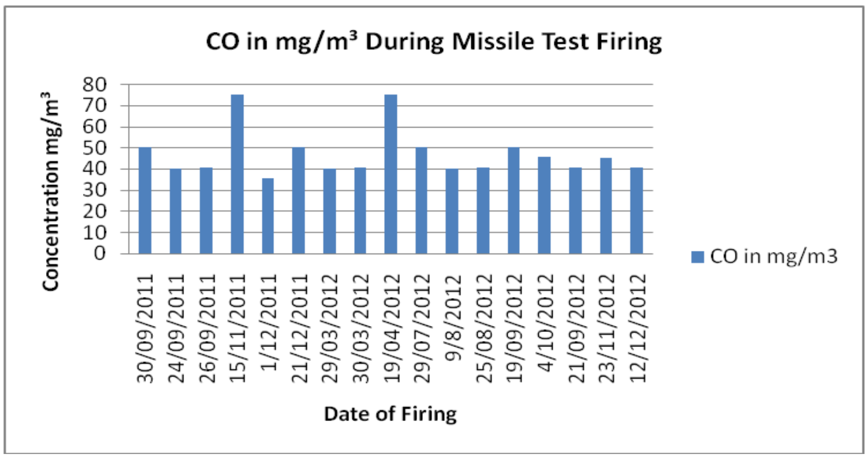


**Figure 7**

CO in mg/m³ During Missile Test Firing

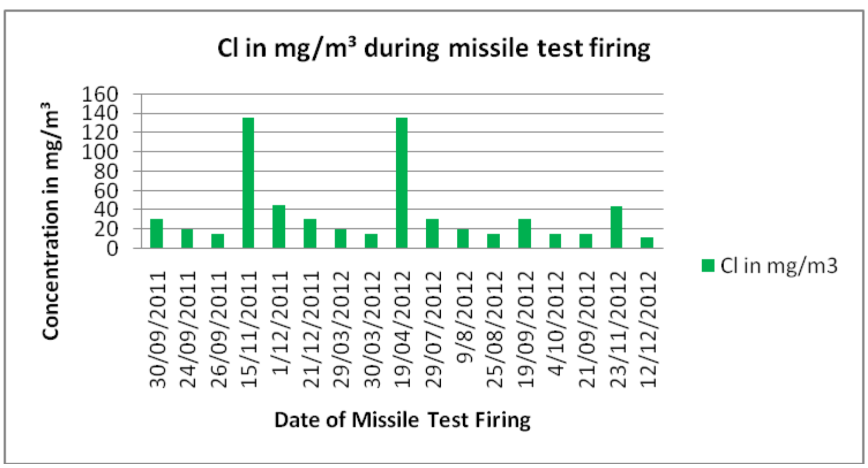


**Figure 8**

Cl in mg/m³ During Missile Test Firing

It was found that the RPM value ranged from 56 µg/m³ 67.8 µg/m³, which was within the standard of CPCB. The normal value after test firing indicated the quick dispersion of RPM and momentary persistence in the atmosphere (Grag, 1998). During test firing

of missiles different toxicants like $SO_2$, NOx, CO, HCN Cl etc are released momentarily and add to the ambient air. To assess the value of these pollutants before test firing, during and after test firing the gaseous exhaust was monitored. The $SO_2$, NOx, CO, HCN & Cl concentrations at different launch pads before firing were monitored and are presented in the graphs (Figures 4 to 8). From the result it is found that $SO_2$ concentration ranged from 1.2 to 7.6 µg/m$^3$. NOx concentration ranged from 2.4 µg/m$^3$ to 18.56 µg/m$^3$ and HCN, CO & Cl concentration were either negligible or below detection level before test firing. But during test firing $SO_2$ concentration ranged from 9.32 µg/m$^3$ to 26. 65 µg/m$^3$ against safety standard of 80 µg/m$^3$ ; NOx concentration ranged from 25.05 µg/m$^3$ to 39.35 µg/m$^3$ against safety standard of 80µg/m$^3$; HCN concentration was between 11.4 µg/m$^3$ to 85 µg/m$^3$, CO concentration ranged from 40 µg/m$^3$ to 75 µg/m$^3$ ; Chloride concentration ranged from 11.5 µg/m$^3$ to 45.3 µg/m$^3$. All the values of the toxicants were within the permissible safety standard. During test firing of different missiles, the sound pressure levels were also measured very near to the launch pads, the results of which are presented in the Figure 9. From the results monitored the sound pressure level was found to be 109.8 dB(A) as minimum sound pressure level and 142.3dB(A) as maximum sound pressure level. The persistence of the sound pressure level was only for a moment i.e., for few second only.

## 5. CONCLUSION

Combustion of propellant during rocket launch generates a lot of toxic gaseous pollutants to the local atmosphere. To know the concentration of toxic gases monitoring was carried out an hour after the test firing and tested for different parameters like $SO_2$, $NO_X$, CO, HCN & Cl. It was found that concentration of toxic gases like $SO_2$, $NO_X$, CO, HCN & Cl decreased and was stable within the safety norm of CPCB. The value of $SO_2$ ranged from 1.2 µg/m$^3$ to 7.60 µg/m$^3$, $NO_X$ ranged between 2.24 µg/m$^3$ to 18.56 µg/m$^3$, which were almost same as before test firing. The value of HCN, CO and Cl were either negligible or below the detection level. Hence, it was seen that whatever toxicants were produced during test firing were diluted and dispersed to normal conditions very quickly which may be due to geographical location of the test firing area and prevailing wind conditions at the sea shore.

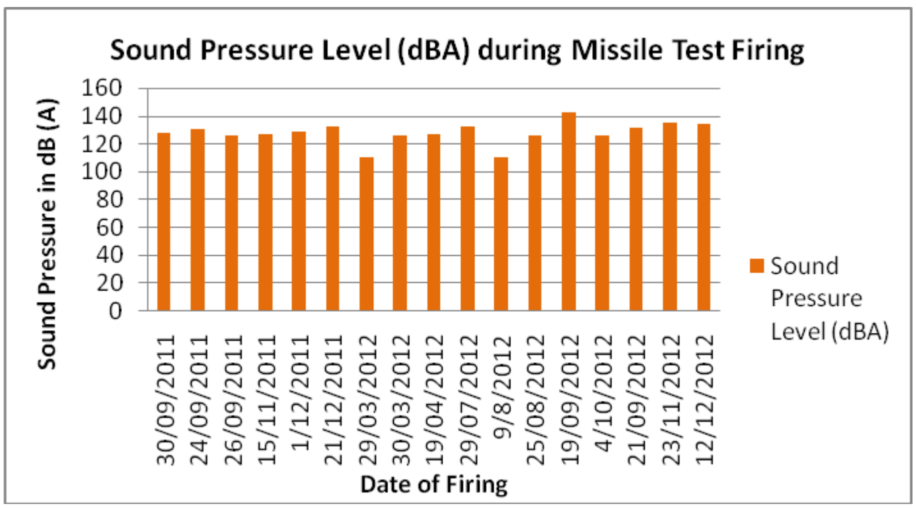


**Figure 9**

Sound Pressure Level (dBA) during Missile Test Firing

**Table 3**

Mole fraction of combustion gaseous exhaust product of Composite Propellant

| Composition | Chamber | Throat | Exit |
|---|---|---|---|
| AL | 1.08E-03 | 5.99E-04 | 2.66E-07 |
| ALCL | 6.78E-03 | 5.05E-03 | 5.88E-05 |
| $ALCL_2$ | 1.41E-03 | 1.13E-03 | 4.36E-05 |
| $ALCL_3$ | 1.51E-05 | 1.29E-05 | 1.53E-06 |
| ALH | 1.32E-04 | 6.42E-05 | 1.60E-08 |
| ALO | 1.07E-03 | 5.65E-04 | 1.73E-07 |
| ALOCL | 1.98E-03 | 1.53E-03 | 2.75E-05 |

| | | | |
|---|---|---|---|
| ALOH | 1.45E-03 | 9.63E-04 | 5.46E-06 |
| $ALO_2$ | 2.29E-04 | 1.23E-04 | 4.27E-08 |
| $ALO_2H$ | 1.94E-03 | 1.31E-03 | 9.33E-06 |
| $AL_2O$ | 3.31E-04 | 1.51E-04 | 0.00E+00 |
| $AL_2O_3$(L) | 8.49E-02 | 8.81E-02 | 9.74E-02 |
| CO | 2.69E-01 | 2.71E-01 | 2.77E-01 |
| COCL | 9.40E-06 | 5.94E-06 | 1.02E-07 |
| $CO_2$ | 1.54E-02 | 1.57E-02 | 2.06E-02 |
| CL | 8.74E-03 | 8.26E-03 | 1.47E-03 |
| CLO | 1.19E-05 | 7.47E-06 | 2.64E-08 |
| $CL_2$ | 6.61E-06 | 5.37E-06 | 3.37E-07 |
| H | 6.10E-02 | 5.43E-02 | 7.44E-03 |
| HCL | 4.56E-02 | 4.93E-02 | 6.73E-02 |
| HCN | 1.41E-05 | 8.41E-06 | 2.52E-07 |
| HCO | 2.48E-04 | 1.63E-04 | 5.65E-06 |
| $H_2$ | 2.10E-01 | 2.16E-01 | 2.47E-01 |
| $H_2O$ | 1.00E-01 | 1.01E-01 | 1.06E-01 |
| N | 4.23E-05 | 2.40E-05 | 4.36E-08 |
| NH | 4.86E-05 | 2.74E-05 | 9.62E-08 |
| $NH_2$ | 2.78E-05 | 1.65E-05 | 2.05E-07 |
| $NH_3$ | 1.32E-05 | 8.68E-06 | 6.68E-07 |
| NO | 2.41E-03 | 1.73E-03 | 3.04E-05 |
| $N_2$ | 1.66E-01 | 1.68E-01 | 1.75E-01 |
| O | 2.69E-03 | 1.88E-03 | 1.20E-05 |
| OH | 1.62E-02 | 1.28E-02 | 5.91E-04 |
| $O_2$ | 5.04E-04 | 3.49E-04 | 2.17E-06 |
| | 1.00E+00 | 1.00E+00 | 1.00E+00 |

## SUMMARY OF RESEARCH

1. During 2011–13, there were 17 No of test firing of different types of missiles during different dates from LC - I, LC-II & LC-III in Chandipur & LC-IV in Dhamra.
2. To know the concentration of toxic gases after test firing monitoring were carried out after an hour for different parameters like RPM, $SO_2$, $NO_X$, CO, HCN & Cl.
3. From the results it was found that all the parameters were well within the prescribed norm before and after rocket firing, but in case of during rocket firing RPM values were above the standard norm i.e. 100μg/$m^3$ and also this became normal within an hour.
4. The value of $SO_2$ ranged from 1.2 μg/$m^3$ to 7.60 μg/$m^3$, $NO_X$ ranged between 2.24 μg/$m^3$ to 18.56 μg/$m^3$, which were almost same as before test firing.
5. The value of HCN, CO and Cl were either negligible or below the detection level.

## FUTURE ISSUES

Experiment shall be carried out about the rate of dilution of toxicant with respect to lapse of time, effect of toxicant on local environment such as flora and fauna as well to structure, effect of toxicant on local climate.

## DISCLOSURE STATEMENT

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## REFERENCE


1. APHA. Methods of Air Sampling and Analysis. Second Edition (*APHA Washington* D.C). 1977
2. Garg SK. Sewage, Disposal and Air Pollution Engineering, 11th Ed, (*Khana Publishers, New Delhi, India*), 1998. p.608
3. Jacob MB, Hochheiser S. Continuous sampling and untra-micro determination of nitrogen dioxide in air. *Anal. Chem*. 1958. 30, 426
4. Orissa Census, District Statistics Hand Book, Balasore. 2007, Directorate of Economics and Statistics, Govt. of Orissa, 2001. Bhubaneswar, India
5. Panda SP, Sahu SK, Sadafule DS, Thakur JV. *J. of Propulsion and Power*, 2000. 16(4), p.723
6. Panigrahi T, Satpathy JK, Sahu SK, Panda RB. Environmental Safety Assessment of Rocket Combustion, *International Journal on Environmental Sciences*, 2012, 3(2), 257-262
7. Sahu SK, Panda SP, Sadafule DS, Kumbhar CG, Kulkarni SG, Thakur JV. *Polymer Degradation and Stability*, 1998. 62, p.495
8. Sahu SK, Raj RA, Panda RB. Proc. of 7th International High Energy Materials Conference and Exhibit, HEMRL, Pune, 2009. p. 10.6
9. Sharma BK. Environmental Chemistry. *Krishna Prakashan Media* P (LTD). Meerut- 25000 (UP) India. Unit-3, 2004. pp-3-40
10. Sutton GP. Rocket Propulsion Elements, 6th Ed *(John Wiley and Sons, New York*), 1992. p.432
11. West PW, Gaeke GC. Fxation of Sulphur Dioxide as Sulfitomercurate-III and Subsequently Colorimetric Determination. *Anal. Chem*., 1956, 28, 1816